Penetrating Head and Neck Trauma

A Narrative Review of Evidence-Based Evaluation and Treatment Protocols

James M. Hamilton, MD[a,b,*], Tyler G. Chan, BS[c], Charles E. Moore, MD[a,b]

KEYWORDS

• Head and neck trauma • Penetrating injury • No-zone framework
• Evidence-based protocols

KEY POINTS

- Penetrating injury to the head and neck accounts for a minority of trauma but significant morbidity in the US civilian population.
- The 3-zone anatomical framework has historically guided evaluation and management; however, the most current evidence-based protocols favor a no-zone approach.
- In stable patients, a thorough physical examination and noninvasive imaging should be prioritized, with surgical exploration of the head and neck reserved for certain circumstances.
- Diagnostic and management decisions should be tailored to the patient's mechanism of injury, trauma history, physical examination, experience of personnel, availability of equipment, and clinical judgment.

INTRODUCTION

Head and neck trauma poses diagnostic and management challenges due to the complexity and importance of the aerodigestive, vascular, and neurologic structures contained within.[1] Although this small anatomical region represents only 2.9% of all trauma cases in the United States, its case fatality rate is 17.36%—the highest rate of all body regions.[2] Given this mortality rate, protocols governing the evaluation,

[a] Department of Otolaryngology–Head and Neck Surgery, Emory University School of Medicine, Atlanta, GA, USA; [b] Department of Otolaryngology–Head and Neck Surgery, Grady Memorial Hospital, Atlanta, GA, USA; [c] Emory University School of Medicine, Atlanta, GA, USA
* Corresponding author. Department of Otolaryngology-Head and Neck Surgery, Emory University School of Medicine, 80 Gilmer Street, 6th Floor, Atlanta, GA 30303.
E-mail address: james.hamilton@emory.edu

Otolaryngol Clin N Am 56 (2023) 1013–1025
https://doi.org/10.1016/j.otc.2023.05.006 **oto.theclinics.com**

triage, and management of patients with penetrating head and neck trauma must be closely examined to optimize patient outcomes.

Penetrating neck trauma is defined as injury that pierces deep to the platysma muscle.[3] The most common mechanism worldwide is stab wounds, followed by gunshot wounds (GSWs), self-harm, road traffic accidents, and other high-velocity objects.[4] Through World War II, surgical exploration was the primary diagnostic and therapeutic modality for such injuries, likely due to the absence of informative diagnostic techniques and high morbidity associated with delayed treatment.[5] An anatomically guided classification that delineated the head and neck region into zones was introduced in 1969 to describe the location of injury and provide a framework to consider injuries to structures housed within each zone.[6,7] The current 3-zone classification evolved from this delineation and has since featured prominently in many protocols[8] (**Table 1**).

Traditionally, when evaluating hemodynamically stable patients with penetrating neck trauma, this framework has mandated surgical exploration of injuries to Zone 2, and recommended a more selective approach for the other zones due to difficult surgical access to the skull base and thoracic inlet.[8] More recently, the widespread availability of high-quality cross-sectional imaging such as computed tomography angiography (CTA) has challenged the paradigm of mandated surgical intervention.[9]

NATURE OF THE PROBLEM

Unstable patients who present with "hard" signs of vascular or aerodigestive tract injury warrant emergent surgical exploration.[10] Whether to operate on stable patients with "soft" signs, or asymptomatic patients, is less clear.[11] Problems associated with the zone-based approach include high-negative neck exploration rates in stable injuries (13%–19%), poor correlation between the wound location and internal organ injuries, and difficulty grouping multilevel injuries into one zone.[10] Routine neck exploration in hemodynamically stable patients results in longer hospitalizations and

Table 1
Historic divisions of penetrating head and neck injury into zones

Zone	Boundaries	Structures
3	Skull base to angle of mandible	Vascular: carotid arteries, jugular veins, vertebral arteries Pulmonary: pharynx Gastrointestinal: N/A Neurologic: spinal cord, cranial nerves, sympathetic chain ganglia Other: salivary glands
2	Angle of mandible to cricoid cartilage	Vascular: internal/external carotid arteries Pulmonary: pharynx, larynx Gastrointestinal: esophagus Neurologic: spinal cord, vagus nerve, recurrent laryngeal nerve Other: N/A
1	Cricoid cartilage to clavicles	Vascular: subclavian artery/vein, vertebral artery/vein, carotid arteries, jugular veins Pulmonary: trachea, lungs Gastrointestinal: esophagus Neurologic: spinal cord, vagus nerve Other: thoracic duct, thyroid gland

Adapted from Weale R, Madsen A, Kong V, Clarke D. (2019). The management of penetrating neck injury. Trauma, 21(2), 85-93.

increased rates of complications (surgical site infections, sepsis, and so forth).[12] Yet there are no international consensus guidelines regarding decisions to operate.

With the advent of CTA, most current evidence-based studies support a shift away from zone-based algorithms toward less-invasive diagnostic procedures and selective surgery after consideration of the patient's status.[1,4,9–11,13–15] This is termed the "no-zone" approach. The goal of this review is to outline current evidence-based practices for evaluation and management of penetrating head and neck trauma.

EVALUATION

Signs of injury in penetrating neck trauma can be classified as "hard" or "soft" based on severity (**Table 2**). Patients may also be asymptomatic. Physical examination is indicated in all patients with penetrating wounds to the head or neck, due to its high sensitivity for injury detection[16,17] and the high risk of decompensating from asphyxiation and exsanguination.[12,18] Initial evaluation involves resuscitation according to advanced trauma life-support principles. A patent airway is the first priority. If airway compromise is suspected, rapid-sequence intubation is indicated when anatomic structures of the head and neck are preserved and airway anatomy can be clearly visualized. Intubation should occur only with clear visualization,[4,19,20] to avoid forcing air into injured tissue planes or further distorting airway anatomy.[4,21,22] Fiberoptic laryngoscopy can help achieve visualization. If intubation fails, or is precluded by disfiguring facial injuries, either immediate emergent tracheotomy or cricothyrotomy is

Table 2
Hard" and "Soft" signs of head and neck injury

Hard Signs	Soft Signs
Vascular	• Stable hematoma
• Refractory shock	• Hoarseness
• Rapidly expanding hematoma	• Dysphagia
• Uncontrolled hemorrhage	• Mild subcutaneous emphysema
• Absent pulse	• Mild hematemesis/hemoptysis
• Audible bruit or palpable thrill	• Dysphonia
Respiratory	• Odynophagia
• Airway compromise	• Chest pain
• Wound bubbling	
• Subcutaneous emphysema	
• Stridor/hoarseness	
• Massive hemoptysis	
• Air sucking in and out	
• Impaired speech	
• Cyanosis	
• Respiratory distress	
• Air bubbling from wound site	
Esophageal	
• Severe dysphagia	
• Significant hematemesis	
Neurologic	
• Neurological deficits	

The presence of any "hard" sign is an indication for surgical exploration of penetrating head and neck trauma.

Adapted from Chandrananth, M. L., Zhang, A., Voutier, C. R., Skandarajah, A., Thomson, B. N. J., Shakerian, R., & Read, D. J. (2021). 'No zone' approach to the management of stable penetrating neck injuries: a systematic review. ANZ journal of surgery, 91(6), 1083–1090.

indicated. Once the airway is secured, attention should turn to hemodynamics and establishing intravenous access before surgical intervention. Direct laryngoscopy, bronchoscopy, or esophagoscopy should be used as necessary to further identify injuries across systems and guide management.[23]

CONSIDERATIONS

The management of patients who present with soft signs or no symptoms is less clear. A benign-appearing entry site can belie the severity of injury because the depth and trajectory of penetration are hidden.[21] The degree of tissue damage depends on the kinetic energy transferred from the penetrating object to the neck tissue,[24] which in turn depends on the mass and velocity of the missile.[18] The energy of a projectile can radiate beyond the perforation site, creating a cavity up to 30 times its size.[25] Thus, penetrating injuries to the head and neck are considered life-threatening until proven otherwise.[21,22]

Injuries from knives or thrown objects generally cause less damage than ballistic injuries, which are more difficult to assess.[26] GSWs can be divided into low-velocity and high-velocity injuries. Small-caliber handguns cause less collateral tissue damage along the projectile path than high-powered rifles or shotguns, which produce a large

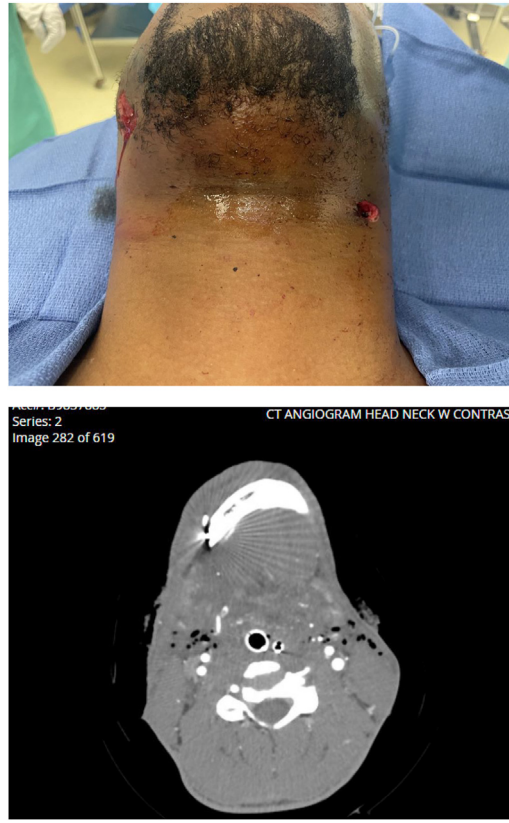

Fig. 1. A 31-year-old man with a GSW to left neck zone II with CTA showing no vascular injury. Given the lack of hard signs of vascular and respiratory injury and stable vital signs, neck exploration was avoided and patient underwent elective repair of mandible fracture on hospital day 2.

concussive wave that can disrupt tissue, rupture blood vessels and nerves, and fracture bones despite their distance from the permanent cavity of the missile (Fig. 1).[27] Structures distant from the entry site must also be evaluated. Impaled objects should not be removed until the extent of injury can be elucidated, and wounds should not be blindly probed, to avoid iatrogenic injury.[21,24] Knowledge of the mechanism of injury is useful in predicting damage and crucial for proper management.[25]

THE DECISION TO OPERATE

Three anatomic zones have been used to categorize wounds by entry location and to guide treatment (see Table 1).[4,7,8,25] Using this algorithm, a penetrating wound of Zone 2 in stable patients is an indication for surgical exploration, and patients with a Zone 1 or 3 injury should undergo endoscopy and angiography due to more difficult surgical access to these regions.[28] There has been unclear benefit of civilian adoption of mandatory surgical intervention as negative neck exploration rates are reported as high as 56%.[10] These highly invasive, labor-intensive procedures also increase complication rates and prolong hospitalization.[27,29–31] Furthermore, location of entry and injury often do not correlate with underlying structures.[32] Thus, management based solely on zones can easily result in inappropriate management decisions.

Historically, various imaging modalities have been used, including 4-vessel digital subtraction angiography,[33] color Doppler,[34] and magnetic resonance angiography. Universal application has been impractical, however, due to risk of complications, operator dependency, and magnetic interaction with possible impaled objects, respectively. More recently, spiral multidirectory CTA has become the favored diagnostic imaging tool due to its high-quality images, speed, and minimally invasive nature. With its low cost and widespread availability in modern trauma centers, it has become an integral to the selective, symptom-based approach[9] that has greatly simplified the management of penetrating neck trauma while reducing the number of missed injuries and negative neck exploration rates.[10]

No-Zone Systems-Based Management

Treatment using the no-zone approach is based on the classification of symptoms that may reflect damage to the major organ systems.

Vascular

Up to 25% of penetrating head and neck injuries result in vascular trauma, including intimal flap, arteriovenous fistula, pseudoaneurysm, and rupture. Mortality rate approaches 50%.[14,24,35,36] The mechanism of death is often exsanguination.[37] Therefore, the presence of hard signs of vascular head and neck trauma warrants surgical exploration.[4] The most common vascular injury from penetrating neck trauma is to the common carotid artery in Zone 2. Damage to the vertebral arteries is rare but possible, with risk factors for stroke and mortality more closely associated with medical history and associated injuries than with treatment decisions.[38,39] Interruption of vertebral artery blood flow is well tolerated due to excellent posterior circulation, and ligation or embolization is the treatment of choice in most injuries requiring intervention.[6,38] Bilateral internal jugular vein injury warrants careful management due to the potential for facial and cerebral edema.[40]

Laryngotracheal

Injury of the larynx and trachea is uncommon in penetrating head and neck trauma but can incur substantial morbidity and mortality if not detected and addressed promptly.[41,42] Once the airway is secure, attention can turn to the location and extent

of injury. In stable patients, chest radiograph can help identify tracheal deviations or bone fractures. Vocal cord function should be assessed with flexible laryngoscopy. Direct laryngoscopy or rigid bronchoscopy may be used to localize injury. Exposed or structurally compromised cartilage must be addressed surgically to maintain airway patency and long-term preservation of phonation. Voice quality and airway patency may be improved when surgery is performed within 24 hours.[43]

Noninvasive procedures include head-of-bed elevation and antiemetics for reflux precautions, serial physical examination to assess for progressive airway compromise from occult hematoma, and steroids to control edema.

Pharyngoesophageal

The reported incidence of injuries to the pharynx and esophagus is under 10%.[41] Although most recommend a conservative approach to surgical intervention,[42,44] delayed recognition and treatment of pharyngoesophageal injury leads to increased morbidity and mortality due to leakage of digestive fluids through occult injuries producing necrotic inflammatory responses.[45,46] Mortality rates up to 20% have been reported.[47,48] Others cite high false-negative rates and advocate for wide, early use of esophagography and rigid esophagoscopy.[49,50]

Neurologic. Neurologic structures at risk of involvement include the spinal cord, cranial nerves, the sympathetic chain, peripheral nerve roots, and the brachial plexus.[4] Spinal cord injuries represent less than 1% of penetrating neck injuries; however, their sequelae can be devastating.[26] Spinal cord transection above C5 will produce paraplegia and can cause respiratory distress from disrupted innervation to the diaphragm. Spinal cord lesions can also elicit neurogenic shock from unopposed parasympathetic and vagal tone; therefore, signs of hypotension or bradycardia should be carefully monitored.[21] Placement of a cervical collar is not routinely recommended in the absence of neurological signs as unnecessary immobilization of the cervical spine may actually hinder management by obscuring airway visualization, hiding injuries, and obstructing assessment of neck wounds.[4]

A comprehensive neurologic examination is warranted as part of the initial survey and should be documented on all patients to identify the extent and timing of any deficit.[21] Injury to the facial nerve can result in impaired eyelid closure, oral incompetence, and mastication difficulty. Vagal nerve injury can impair vocal cord mobility, leading to dysphonia, dysphagia, aspiration, and airway compromise. Patients with penetrating neck injuries are also at risk of cerebrovascular insults from temporary or prolonged ischemia or released emboli from compromised vertebral or carotid arteries.

Penetrating trauma of the face

Penetrating facial trauma presents its own diagnostic and management challenges. The National Trauma Data Bank reports a case fatality rate of 14.9%.[2] GSWs are most common in the United States[51] and can be categorized as nonpenetrating (abrasion of the skin), penetrating (the projectile enters but does not exit the face), perforating (presence of entry and exit points), or avulsive (entry and exit with substantial tissue loss).[52] The primary objective is to sustain life, followed by restoration of facial form and function. Once patients have been stabilized and imaging obtained, repair and reconstruction are implemented according to the reconstructive ladder.

The rate of surgical intervention after facial GSWs ranges from 38% to 100%,[53] with few guidelines regarding the decision to operate.[51,53,54] A study of patients with isolated facial GSWs showed an association between location and surgical intervention: injuries to the lower face (below the occlusal plane to the angle of the mandible) required surgical intervention more often (87.2%) than those to the upper (60%;

supraorbital rim to infraorbital rim) or middle face (29.6%; infraorbital rim to occlusal plane).[55] Another study categorized facial GSWs by location of injury: temporal, frontal, intraoral, submental, or neck.[56] Mortality was 82% among patients with temporal bone injury versus 14% for submental injury, suggesting that proximity of entry wounds to the cranial cavity is predictive of mortality.

Another study of lower face injuries emphasized the timing of treatment.[51] The authors divided time after admission into emergency (day of presentation), immediate surgery (within 72 hours), delayed surgery (72 hours to 2 weeks), and secondary intervention (after 2 weeks) phases and recommended addressing fractures within 72 hours for best results, with exceptions for concomitant life-threatening or cranial injuries mandating earlier attention. They also recommended delayed osseous reconstruction to allow adequate time for soft-tissue closure. Others advocate delay to allow edema to resolve, facilitating better assessment of facial contours and optimal esthetic outcomes after reconstruction.[57,58] Nonetheless, immediate reconstruction confers benefits such as reductions in tissue fibrosis, length of hospitalization, and periods of suboptimal esthetic appearance.

Current Evidence

Growing evidence supports giving more emphasis to patients' signs, symptoms, and imaging in dictating investigation and management.[10] Multiple studies of patients undergoing CTA, including several prospective studies, reported sensitivity of 93.9% to 100% and specificity of 93.5% to 97.5% in detecting all vascular and aerodigestive injuries regardless of ultimate treatment modality.[10,11,13,15,52,59]

Patients with Hard Signs

The literature shows consensus in advocating for mandatory surgical exploration in patients who present with hard signs[52,59,60] (**Fig. 2**), although some evidence suggest that preoperative CTA is reasonable (**Fig. 1**). A recent study identified no significant difference in missed injuries between CTA and surgical exploration in patients with Zone 2 injuries presenting with hard signs, with rates of negative neck exploration of 0% in the CTA group versus 36% in the operative group.[15] In another study of patients with hard signs who underwent CTA due to hemodynamic stability, 61.5% underwent surgery, allowing 38.5% to avoid neck exploration.[13] Another study reported a decrease in negative neck exploration rate from of 23% to 15% with use of CTA among stable patients with hard signs.[61] All studies showed decreased rates of negative neck exploration with no consequent complications, missed injuries, or mortality.[13,15,61] Thus, preoperative CTA in patients presenting with hard signs may be warranted if the patient can be stabilized (see **Fig. 1**).

Patients with Soft Signs

A prospective, single-center cohort study evaluated the benefit of CTA screening in the initial evaluation of patients with penetrating neck injuries who were symptomatic with soft signs.[52] Of these, 17.7% required surgery, meaning 82.3% avoided unnecessary neck exploration. Another study reported a negative neck exploration rate of 0% for patients who underwent CTA, with a rate of 48% reported for 27 non-CTA patients.[62] Other reports similarly found that the use of CTA led to the avoidance of negative neck exploration in 51.7% to 97.7% of patients with soft signs.[10,61,63,64] These studies support management with CTA and close observation, showing very few missed injuries or complications in patients with soft signs.

Fig. 2. A 29-year-old man with a self-inflicted knife wound to the anterior neck in zone II underwent neck exploration due to active hemorrhage, respiratory distress and stridor, and exposed laryngeal cartilage. Bilateral carotid arteries were found to be intact but a transection of the thyro-hyoid membrane was identified with open communication of the lumen of the hypopharynx and larynx. Wound was evaluated with intraop direct laryngoscopy, flexible esophagoscopy, and bronchoscopy. Injury was repaired primarily with mucosal inverting stitches and bolstered with a rotational muscle flap using strap muscles.

Patients with No Signs

For asymptomatic patients, diagnosis and management modalities are also unclear. Although mandatory neck exploration is less advised, the benefit of CTA is less established. Many studies support the use of thorough physical examination. Several studies have shown no missed injuries reported no further complications with serial physical examinations and close observation.[10,59] Another study reported that among 99 asymptomatic patients, 3 revealed positive CTA findings, with none resulting in delayed complications or requiring surgery.[63] However, one study found that 2 of 41 asymptomatic patients had injury (tracheal puncture and pseudoaneurysm) after CTA,[52] and another showed vascular injury in 5% of asymptomatic patients who underwent CTA based on the surgeon's discretion; these were all GSWs.[13] Therefore, CTA may not be indicated in most asymptomatic patients, perhaps except for those with GSWs.

Potential Drawbacks

Despite the benefits of CTA, occult injuries have been discovered on surgical exploration not identified on CTA.[65,66] Historically, the morbidity and mortality of missed esophageal injuries was a strong driver of mandatory surgical exploration.[3] One study indicated the sensitivity of CTA in detecting pharyngoesophageal injuries to be as low as 53%.[47] A punctured airway or perforated esophagus is less likely to be detected by

CTA. Thus, barium swallow, esophagoscopy, bronchoscopy, or fluoroscopy added to CTA warrants consideration.[11]

Finally, the false-positive rate of CTA should not be ignored. One study showed 5 false-positive diagnoses of aerodigestive tract injuries that resulted in 2 negative neck explorations.[52] Another showed a false-positive CTA rate of 14.8%.[13] A nonnegligible risk of detecting clinically insignificant injuries might drive further workup or exploration when none is therapeutically necessary. Additionally, the quality of CTA imaging is occasionally hampered by streak artifacts, and IV contrast is contraindicated in some patients.[14,60] Increased radiation burden should also be considered.[59] Thus regardless of CTA findings, a high index of suspicion should be maintained and serial physical examinations performed in all patients with penetrating head and neck trauma to prevent missed injuries.

SUMMARY

Although penetrating trauma to the head and neck is relatively uncommon, the risks of untreated or unrecognized sequelae are potentially life-threatening. The current evidence-based literature favors noninvasive imaging over mandatory surgical exploration, regardless of zone of injury. Imaging triage accomplishes safe, noninvasive evaluation of head and neck structures to rule in or out injury warranting surgical intervention. Invasive algorithms should be replaced with a new standard of care: evidence-based screening strategies comprising physical examination and CTA. Protocols and guidelines continue to evolve as novel diagnostic and therapeutic techniques are introduced to provide optimal outcomes for patients with penetrating injury of the head and neck.

CLINICS CARE POINTS

- High-quality images, speed, and minimally invasive nature have mad spiral multidirectory CTA the favored diagnostic imaging tool due for penetrating trauma to the head and neck. With its low cost and widespread availability in modern trauma centers, it has become an integral to the selective, symptom-based approach that has greatly simplified the management of penetrating neck trauma while reducing the number of missed injuries and negative neck exploration rates.
- Growing evidence supports giving more emphasis to patients' signs, symptoms, and imaging in dictating investigation and management..
- The literature shows consensus for mandatory surgical exploration in patients who present with hard signs of vascular or aerodigestive tract injury, although some evidence suggests that preoperative CTA may be warranted if the patient can be stabilized.
- In the patient with soft signs, the literature supports management with CTA and close observation, showing very few missed injuries or complications in patients with soft signs.
- CTA may not be indicated in most asymptomatic patients, perhaps except for those with GSWs.
- Regardless of CTA findings, a high index of suspicion should be maintained, and serial physical examinations performed in all patients with penetrating head and neck trauma to prevent missed injuries.

DISCLOSURE

The authors have no funding, financial relationships, or conflicts of interest to disclose.

REFERENCES

1. Shiroff AM, Gale SC, Martin ND, et al. Penetrating Neck Trauma: A Review of Management Strategies and Discussion of the 'No Zone' Approach. Am Surg 2013;79:23–9.
2. National Trauma Data bank 2016 Annual Report. American College of Surgeons; 2016.
3. Fogelman MJ, Stewart RD. Penetrating wounds of the neck. Am J Surg 1956; 91(4):581–96.
4. Nowicki JL, Stew B, Ooi E. Penetrating neck injuries: a guide to evaluation and management. Ann R Coll Surg Engl 2018;100(1):6–11.
5. Miller RH, Duplechain JK. Penetrating wounds of the neck. Otolaryngol Clin North Am 1991;24(1):15–29.
6. Kesser BW, Chance E, Kleiner D, et al. Contemporary management of penetrating neck trauma. Am Surg 2009;75(1):1–10.
7. Monson DO, Saletta JD, Freeark RJ. Carotid vertebral trauma. J Trauma 1969; 9(12):987–99.
8. Roon AJ, Christensen N. Evaluation and treatment of penetrating cervical injuries. J Trauma 1979;19(6):391–7.
9. Chandrananth ML, Zhang A, Voutier CR, et al. 'No zone' approach to the management of stable penetrating neck injuries: a systematic review. ANZ J Surg 2021; 91(6):1083–90.
10. Prichayudh S, Choadrachata-anun J, Sriussadaporn S, et al. Selective management of penetrating neck injuries using "no zone" approach. Injury 2015;46(9): 1720–5.
11. Amico F, Bendinelli C, Balogh ZJ. Penetrating neck trauma: No zone, no problem? ANZ J Surg 2021;91(6):1051–2.
12. Ko JW, Gong SC, Kim MJ, et al. The efficacy of the "no zone" approach for the assessment of traumatic neck injury: a case-control study. Ann Surg Treat Res 2020;99(6):352–61.
13. Madsen AS, Kong VY, Oosthuizen GV, et al. Computed Tomography Angiography is the Definitive Vascular Imaging Modality for Penetrating Neck Injury: A South African Experience. Scand J Surg 2018;107(1):23–30.
14. Kee-Sampson JW, Gopireddy DR, Vulasala SSR, et al. Role of imaging in penetrating vascular injuries of the craniocervical region. J Clin Imaging Sci 2022; 12:63.
15. Schroll R, Fontenot T, Lipcsey M, et al. Role of computed tomography angiography in the management of Zone II penetrating neck trauma in patients with clinical hard signs. J Trauma Acute Care Surg 2015;79(6):943–50 [discussion: 950].
16. Eddy VA. Is routine arteriography mandatory for penetrating injury to zone 1 of the neck? Zone 1 Penetrating Neck Injury Study Group. J Trauma 2000;48(2):208–13 [discussion: 213–4].
17. Azuaje RE, Jacobson LE, Glover J, et al. Reliability of physical examination as a predictor of vascular injury after penetrating neck trauma. Am Surg 2003;69(9): 804–7.
18. Siau RT, Moore A, Ahmed T, et al. Management of penetrating neck injuries at a London trauma centre. Eur Arch Oto-Rhino-Laryngol 2013;270(7):2123–8.
19. Tallon JM, Ahmed JM, Sealy B. Airway management in penetrating neck trauma at a Canadian tertiary trauma centre. Cjem 2007;9(2):101–4.
20. Youssef N, Raymer KE. Airway management of an open penetrating neck injury. Cjem 2015;17(1):89–93.

21. Kesser BW, Chance E, Kleiner D, et al. Article Commentary: Contemporary Management of Penetrating Neck Trauma. Am Surg 2009;75(1):1–10.
22. Kendall JL, Anglin D, Demetriades D. Penetrating neck trauma. Emerg Med Clin North Am 1998;16(1):85–105.
23. Paul W, Flint BH, Lund V, et al. Cummings otolaryngology head and neck surgery. Elsevier; 2020.
24. Rhee P, Kuncir EJ, Johnson L, et al. Cervical spine injury is highly dependent on the mechanism of injury following blunt and penetrating assault. J Trauma 2006; 61(5):1166–70.
25. Asensio JA, Valenziano CP, Falcone RE, et al. Management of penetrating neck injuries. The controversy surrounding zone II injuries. Surg Clin North Am 1991; 71(2):267–96.
26. Saletta JD, Lowe RJ, Lim LT, et al. Penetrating trauma of the neck. J Trauma 1976; 16(7):579–87.
27. Demetriades D, Salim A, Brown C, et al. Neck injuries. Curr Probl Surg 2007; 44(1):13–85.
28. Golueke PJ, Goldstein AS, Sclafani SJ, et al. Routine versus selective exploration of penetrating neck injuries: a randomized prospective study. J Trauma 1984; 24(12):1010–4.
29. Obeid FN, Haddad GS, Horst HM, et al. A critical reappraisal of a mandatory exploration policy for penetrating wounds of the neck. Surg Gynecol Obstet 1985;160(6):517–22.
30. Meyer JP, Barrett JA, Schuler JJ, et al. Mandatory vs selective exploration for penetrating neck trauma. A prospective assessment. Arch Surg 1987;122(5): 592–7.
31. Ashworth C, Williams LF, Byrne JJ. Penetrating wounds of the neck: Re-emphasis of the need for prompt exploration. Am J Surg 1971;121(4):387–91.
32. Low GM, Inaba K, Chouliaras K, et al. The use of the anatomic 'zones' of the neck in the assessment of penetrating neck injury. Am Surg 2014;80(10):970–4.
33. Stuhlfaut JW, Barest G, Sakai O, et al. Impact of MDCT angiography on the use of catheter angiography for the assessment of cervical arterial injury after blunt or penetrating trauma. AJR Am J Roentgenol 2005;185(4):1063–8.
34. Montalvo BM, LeBlang SD, Nuñez DB Jr, et al. Color Doppler sonography in penetrating injuries of the neck. AJNR Am J Neuroradiol 1996;17(5):943–51.
35. Stone HH, Callahan GS. SOFT TISSUE INJURIES OF THE NECK. Surg Gynecol Obstet 1963;117:745–52.
36. Saito N, Hito R, Burke PA, et al. Imaging of penetrating injuries of the head and neck:current practice at a level I trauma center in the United States. Keio J Med 2014;63(2):23–33.
37. Hong S, Klem C. Hemorrhage management and vascular control. Textbooks of military medicine otolaryngology/head and neck surgery combat casualty care in Operation Iraqi Freedom and Operation Enduring Freedom Fort Sam Houston (TX). Department of Defense (DOD), The Borden Institute; 2015.
38. Reid JD, Weigelt JA. Forty-three cases of vertebral artery trauma. J Trauma 1988; 28(7):1007–12.
39. Schellenberg M, Owattanapanich N, Cowan S, et al. Penetrating injuries to the vertebral artery: interventions and outcomes from US Trauma Centers. Eur J Trauma Emerg Surg 2022;48(1):481–8.
40. McGovern PJ Jr, Swan KG. Management of bilateral internal jugular venous injuries. Injury 1985;16(4):259–60.

41. Vassiliu P, Baker J, Henderson S, et al. Aerodigestive injuries of the neck. Am Surg 2001;67(1):75–9.
42. Demetriades D, Velmahos GG, Asensio JA. Cervical pharyngoesophageal and laryngotracheal injuries. World J Surg 2001;25(8):1044–8.
43. Bhojani RA, Rosenbaum DH, Dikmen E, et al. Contemporary assessment of laryngotracheal trauma. J Thorac Cardiovasc Surg 2005;130(2):426–32.
44. Madiba TE, Muckart DJ. Penetrating injuries to the cervical oesophagus: is routine exploration mandatory? Ann R Coll Surg Engl 2003;85(3):162–6.
45. Velmahos GC, Souter I, Degiannis E, et al. Selective surgical management in penetrating neck injuries. Can J Surg 1994;37(6):487–91.
46. Armstrong WB, Detar TR, Stanley RB. Diagnosis and management of external penetrating cervical esophageal injuries. Ann Otol Rhinol Laryngol 1994; 103(11):863–71.
47. Bryant AS, Cerfolio RJ. Esophageal Trauma. Thorac Surg Clin 2007;17(1):63–72.
48. Mahmoodie M, Sanei B, Moazeni-Bistgani M, et al. Penetrating neck trauma: review of 192 cases. Arch Trauma Res 2012;1(1):14–8.
49. Weigelt JA, Thal ER, Snyder WH 3rd, et al. Diagnosis of penetrating cervical esophageal injuries. Am J Surg 1987;154(6):619–22.
50. Biffl WL, Moore EE, Rehse DH, et al. Selective management of penetrating neck trauma based on cervical level of injury. Am J Surg 1997;174(6):678–82.
51. Norris O, Mehra P, Salama A. Maxillofacial Gunshot Injuries at an Urban Level I Trauma Center—10-Year Analysis. J Oral Maxillofac Surg 2015;73(8):1532–9.
52. Demetriades D, Chahwan S, Gomez H, et al. Initial evaluation and management of gunshot wounds to the face. J Trauma 1998;45(1):39–41.
53. Chen AY, Stewart MG, Raup G. Penetrating injuries of the face. Otolaryngol Head Neck Surg 1996;115(5):464–70.
54. Qaisi M, Martin S, Al Azzawi T, et al. Is Maxillofacial Gunshot Wound Location Associated With Operative Intervention? J Oral Maxillofac Surg 2023;81(4): 434–40.
55. Murphy JA, Lee MT, Liu X, et al. Factors affecting survival following self-inflicted head and neck gunshot wounds: a single-centre retrospective review. Int J Oral Maxillofac Surg 2016;45(4):513–6.
56. Peleg M, Sawatari Y. Management of gunshot wounds to the mandible. J Craniofac Surg 2010;21(4):1252–6.
57. Ueeck BA. Penetrating Injuries to the Face: Delayed Versus Primary Treatment—Considerations for Delayed Treatment. J Oral Maxillofac Surg 2007;65(6): 1209–14.
58. Inaba K, Munera F, McKenney M, et al. Prospective evaluation of screening multislice helical computed tomographic angiography in the initial evaluation of penetrating neck injuries. J Trauma 2006;61(1):144–9.
59. Inaba K, Branco BC, Menaker J, et al. Evaluation of multidetector computed tomography for penetrating neck injury: a prospective multicenter study. J Trauma Acute Care Surg 2012;72(3):576–83 [discussion 583–4; quiz: 803–4].
60. Munera F, Danton G, Rivas LA, et al. Multidetector row computed tomography in the management of penetrating neck injuries. Semin Ultrasound CT MR 2009; 30(3):195–204.
61. Borsetto D, Fussey J, Mavuti J, et al. Penetrating neck trauma: radiological predictors of vascular injury. Eur Arch Oto-Rhino-Laryngol 2019;276(9):2541–7.
62. Osborn TM, Bell RB, Qaisi W, et al. Computed tomographic angiography as an aid to clinical decision making in the selective management of penetrating

injuries to the neck: a reduction in the need for operative exploration. J Trauma 2008;64(6):1466–71.
63. Ibraheem K, Khan M, Rhee P, et al. "No zone" approach in penetrating neck trauma reduces unnecessary computed tomography angiography and negative explorations. J Surg Res 2018;221:113–20.
64. Hundersmarck D, Reinders Folmer E, de Borst GJ, et al. Penetrating Neck Injury in Two Dutch Level 1 Trauma Centres: the Non-Existent Problem. Eur J Vasc Endovasc Surg 2019;58(3):455–62.
65. Bhatt NR, McMonagle M. Penetrating neck injury from a screwdriver: can the No Zone approach be applied to Zone I injuries? BMJ Case Rep 2015;2015.
66. Tisherman SA, Bokhari F, Collier B, et al. Clinical practice guideline: penetrating zone II neck trauma. J Trauma 2008;64(5):1392–405.